Circuit Analysis

By

Jibreel Bornat

Chapters 1-3

Birzeit University

2025

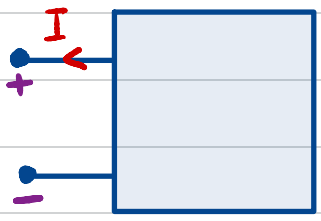
Chapter 1 - introduction

Passive sign convention

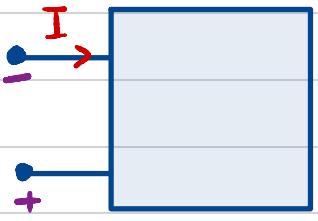
When to put $P = IV$ and when to put $P = -IV$?

$P = IV$

$P = IV$



$P = -IV$



$P = -IV$

السبب:
ضبوط الجهد يكون من الموجب (+) إلى السالب (-)
اذا كان التيار مع اتجاه ضبوط الجهد ⇐ موجب
اذا كان التيار عكس اتجاه ضبوط الجهد ⇐ سالب

باختصار:
التيار داخل من الموجب ⇐ موجب P
التيار داخل من السالب ⇐ سالب P

Note :-
if $P > 0$ ⇒ absorbing (تستهلك طاقة)

if $P < 0$ ⇒ Supplying (تنتج طاقة)

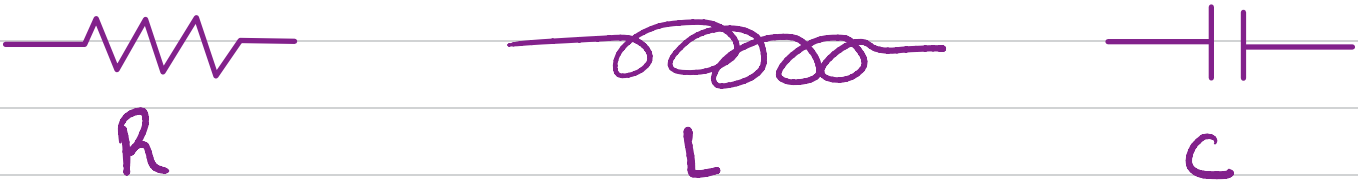
Chapter 2 - Circuit Elements

Ideal circuit elements

are two terminal devices can be Simplified into Passive and active devices.

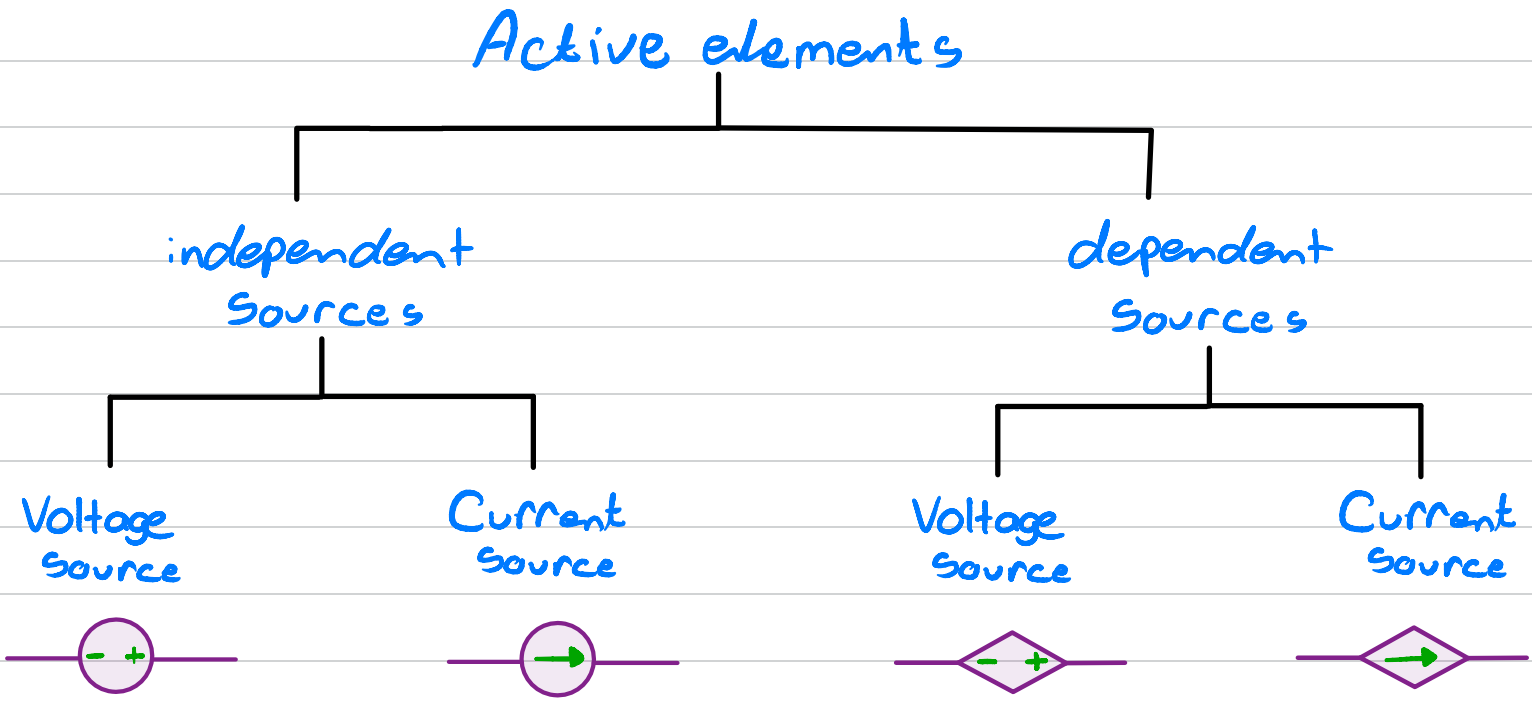
Passive elements

elements that Consume energy

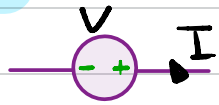


Active elements

elements that Produce energy (like Battery)



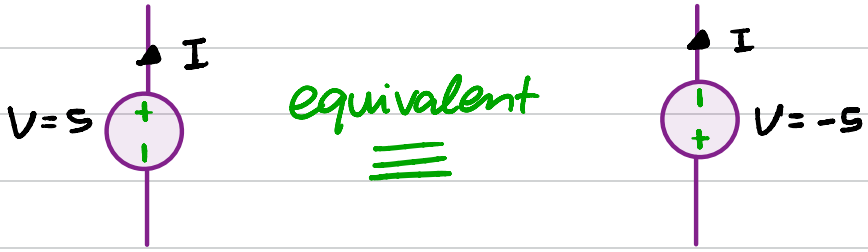
1 - Independent sources :

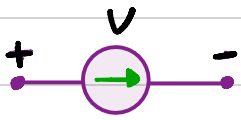
1- Voltage Source  :-

V : Constant

I : depends on the Circuit Connections " I Changes "

ideal independent voltage source : a voltage source that maintains a specific voltage in it.



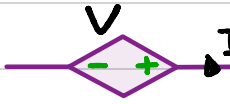
2- Current Source  :-

I : Constant

V : depends on the Circuit Connections " V Changes "

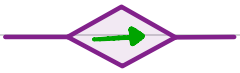
ideal independent Current source : a Current source that maintains a specific Current in it.

2 - Dependent sources :

1- Voltage Source  :-

Case 1 : V = Constant * V_x => Voltage Controlled

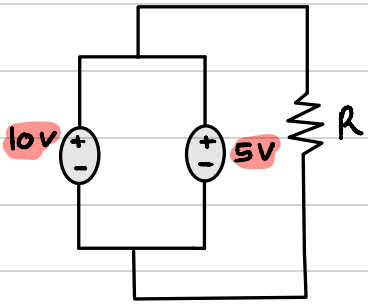
Case 2 : V = Constant * i_x => Current Controlled

2- Current Source  :-

Case 1 : i = Constant * V_x => Voltage Controlled

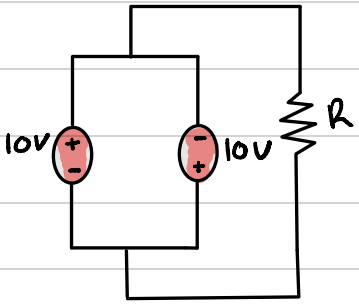
Case 2 : i = Constant * i_x => Current Controlled

Validity of the circuits



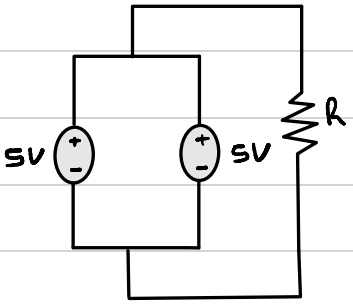
Invalid ✗

لا يجب ان تكون القيم مختلفة



Invalid ✗

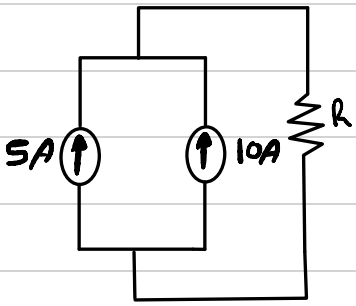
لا يجب ان تكون الاشارة مختلفة



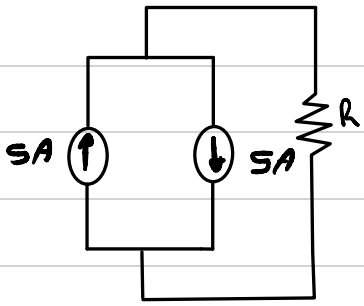
Valid ✓

نفس القيم ✓

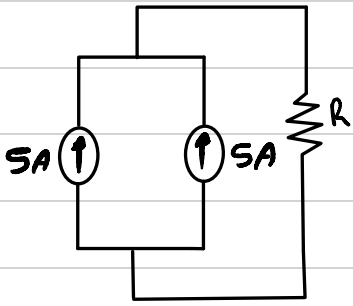
نفس الاتجاه ✓



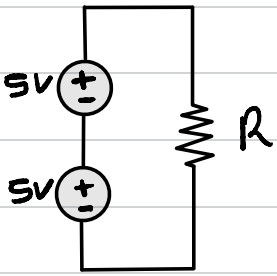
Valid ✓



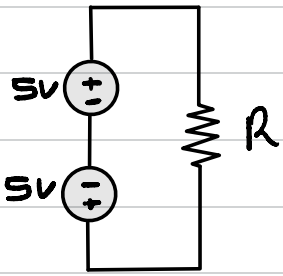
Valid ✓



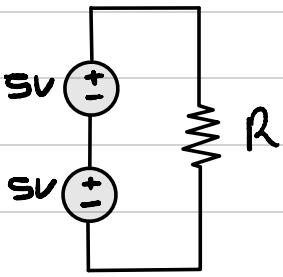
Valid ✓



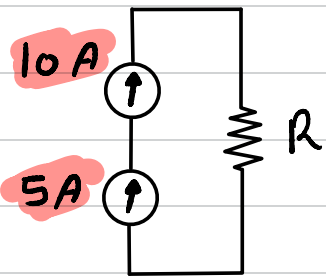
Valid ✓



Valid ✓

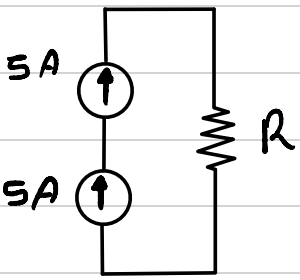


Valid ✓

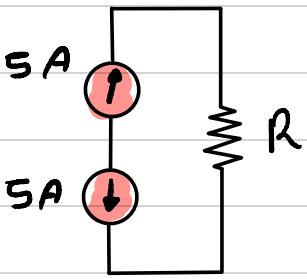


Invalid ✗

لا يجب ان تكون القيم مختلفة



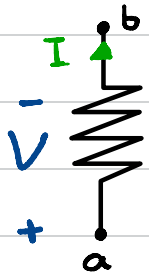
Valid ✓



Invalid ✗

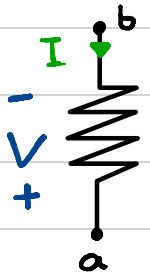
لا يجب ان تكون الاشارة مختلفة

Ohm's law



$V = IR$

التيار داخل من الموجب
القانون موجب ⇐



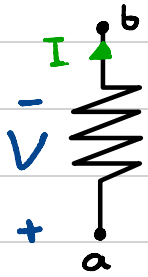
$V = -IR$

التيار داخل من السالب
القانون سالب ⇐

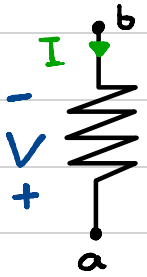
Conductance (G)

$G = \frac{1}{R}$ عكس المقاومة

Power (P)

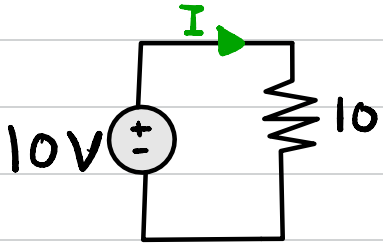


$P = I^2R = \frac{V^2}{R}$



$P = I^2R = \frac{V^2}{R}$

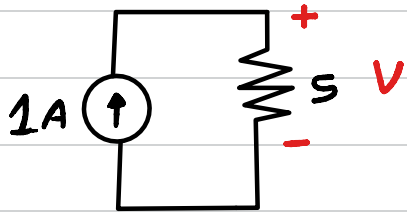
Example- Find V and I ?



$V = 10$

$I = \frac{V}{R} = \frac{10}{10}$

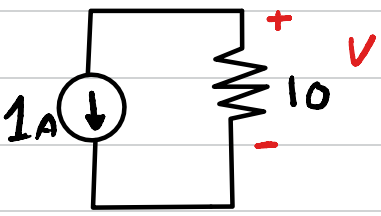
$I = 1$



$I = 1$

$V = IR = 1 * 5$

$V = 5$



$I = 1$

$V = -IR = -1 * 10$

$V = -10$

Kirchhoff Laws

① Kirchhoff current law (KCL)

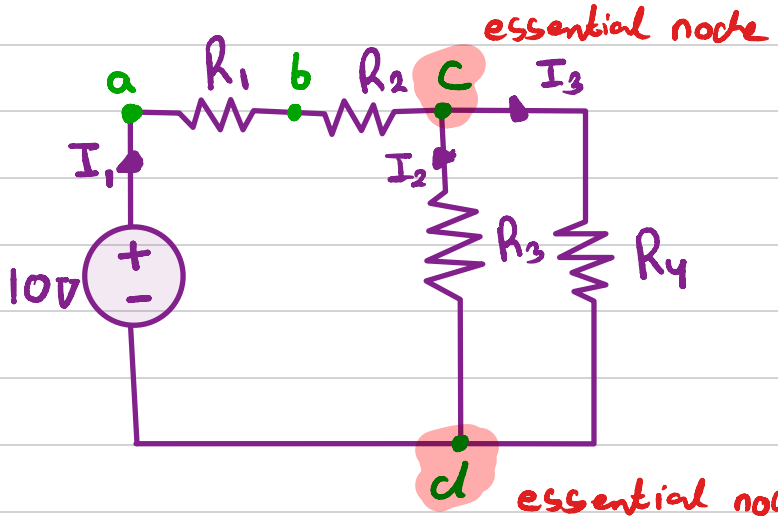
The algebraic sum of the currents at any node equals zero $\Rightarrow \sum I_{in} = \sum I_{out}$

Node

It's a point that connects 2 or more circuit elements

Essential Node

It's a point that connects 3 or more circuit elements



How to solve ?

1- اصب جميع التيارات الداخلة او الخارجة من النقطة

2- أساويها بالصفر، أو $\sum I_{in} = \sum I_{out}$

node a :

$I_1 = I_1$

node c :

$-I_1 + I_2 + I_3 = 0$

node d :

$I_1 - I_2 - I_3 = 0$

*** Note**

im just interested on essential nodes

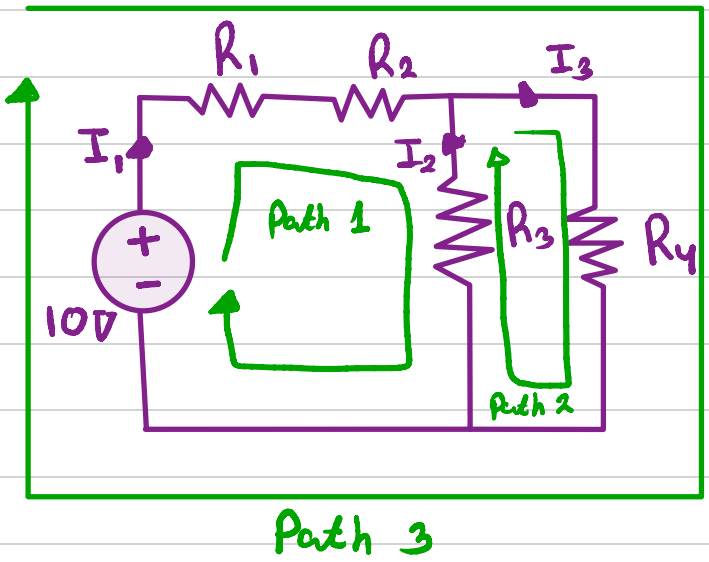
② Kirchhoff voltage law (KVL)

ΣV around any closed path is equal to zero

How to Solve ?

1- draw the path in any direction (it's better to be with I direction)

2- move with the path and don't forget to look at the signs (+-)



Path 1

$I_1R_1 + I_1R_2 + I_2R_3 - 10 = 0$

Path 2

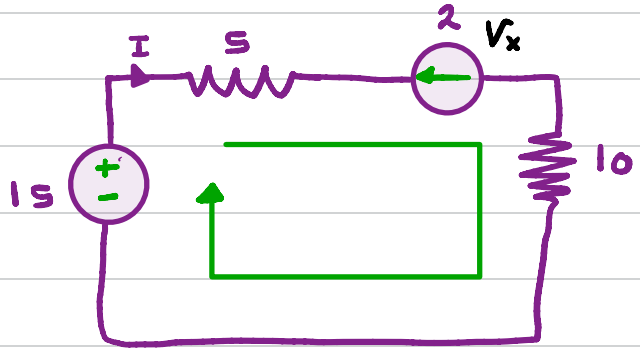
$I_3R_4 - I_2R_3 = 0$

Path 3

$I_1R_1 + I_1R_2 + I_3R_4 - 10 = 0$

Example

write the KVL equation



$I * 5 - V_x + I * 10 - 15 = 0$

$15I - 15 - V_x = 0$

* Since the current source = 2 then I = 2 (Rule)

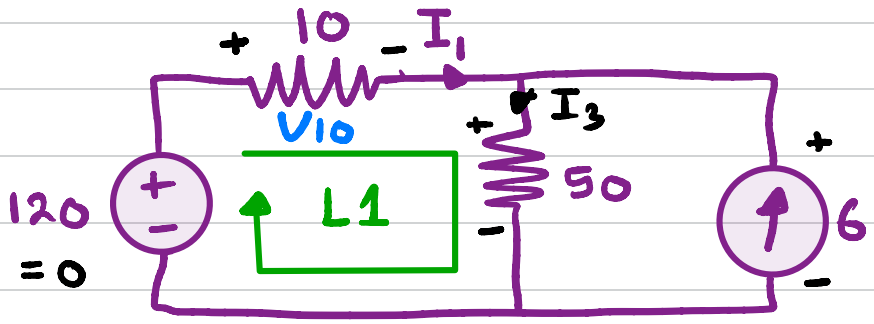
$\Rightarrow 15 * 2 - 15 - V_x \Rightarrow$ **$V_x = 15$**

Why V_x ?

Because the current source has a voltage drop V_x

Example

Find I_1 , P on all Points



Loop 1 :

$I_1 * 10 + (I_1 + 6) * 50 - 120 = 0$

$10 I_1 + 50 I_1 + 300 - 120 = 0$

$60 I_1 = -180$

$I_1 = -3A$

$P_{120} = -(-IV) \Rightarrow P_{120} = -(-3 * 120) \Rightarrow P_{120} = 360\,w$

$P_{10} = I_1^2 R \Rightarrow P_{10} = -3^2 * 10 \Rightarrow P_{10} = 90\,w$

$P_{50} = I_3^2 R \Rightarrow P_{50} = (-3+6)^2 * 50 \Rightarrow P_{50} = 450\,w$

$P_6 = IV$

$V_{10} = IR \Rightarrow V_{10} = -3 * 10 \Rightarrow V_{10} = -30$

$\Rightarrow$ then the voltage of R_{50} and current source is equal to $120 - -30 \Rightarrow V = 150$

$P_6 = -VI \Rightarrow P_6 = -150 * 6 \Rightarrow P_6 = -900\,w$

Why $V = -150$?

Because of the voltage drop from - to +

What if we reverse the voltage drop

then V should equal 150 BUT I will be -6 because we will move backwards

OR

$\Sigma P = 0$

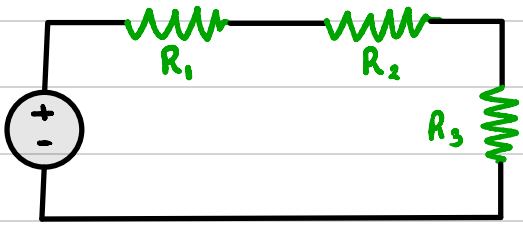
$360 + 90 + 450 + P_6 = 0$

$\Rightarrow P_6 = -900\,w$

Chapter 3 – Simple Resistive Circuits

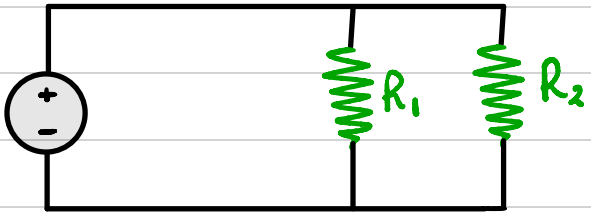
Solving for Resistors in series and resistors in parallel (R_{eq})

R_{eq} in series



$$R_{eq} = R_1 + R_2 + R_3$$

R_{eq} in parallel

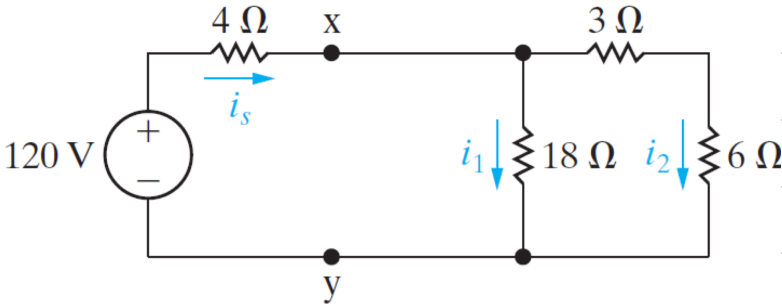


$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$ (2 or more)

or $$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$ (just 2)

Example 1

find i_s , i_1 , i_2



3 with 6 : $3 + 6 = 9$

$9 \,//\, 18$: $\frac{9 * 18}{9 + 18} = 6$

6 with 4 : $6 + 4 = 10 \Rightarrow R_{eq} = 10\ \Omega$

$i_s = \frac{V}{R_{eq}} \Rightarrow i_s = \frac{120}{10} \Rightarrow i_s = 12A$

$V_{xy} = 120 - V_4 \Rightarrow V_{xy} = 120 - (4 * 12) \Rightarrow V_{xy} = 72$

$i_1 = \frac{V_{xy}}{R_{18}} \Rightarrow i_1 = 4A$, then $i_2 = 12 - 4 \Rightarrow i_2 = 8\ A$

Voltage divider rule (VDR)

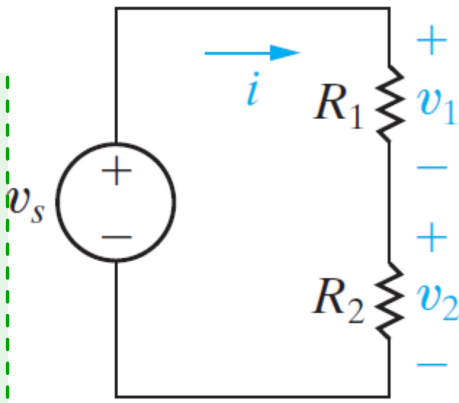
- we use it when we want to find the voltage on a resistors that are in Series.

- it's faster to find the voltages using this method.

The Rule :-

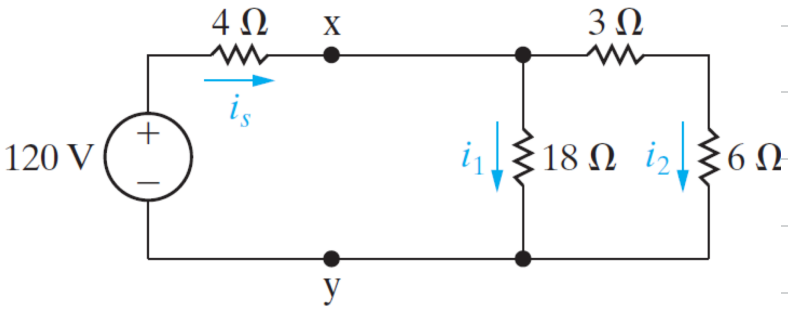
مصدر الجهد المتوزع بينهما * النفس / النفس + الكل

$$V_1 = \frac{R_1}{R_1 + R_2} * V_s \quad , \quad V_2 = \frac{R_2}{R_2 + R_1} * V_s$$



Example 2

Find V_x using VDR



3 with 6 : $3 + 6 = 9$

9 // 18 : $\frac{9 * 18}{9 + 18} = 6$

$$V_x = \frac{6}{6+4} * 120 \Rightarrow V_x = 72 \text{ Volt}$$

Note

- When i see Voltage Sources in Series

$$V_{eq} = V_1 + V_2 + --- + V_n$$

- when i see Current Sources in Paallel

$$I_{eq} = I_1 + I_2 + --- + I_n$$

- When you see Voltage s. and Current s. then you CAN'T apply VDR or CDR

Current dividend rube (CDR)

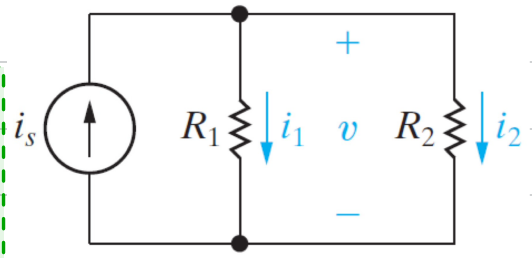
- we use it when we want to find the Current on a resistors that are in Parallel.

- it's faster to find the Current using this method.

The Rule :-

التيار المتوزع بينهم * المقاومة المطلوبة / المقاومة الكلية

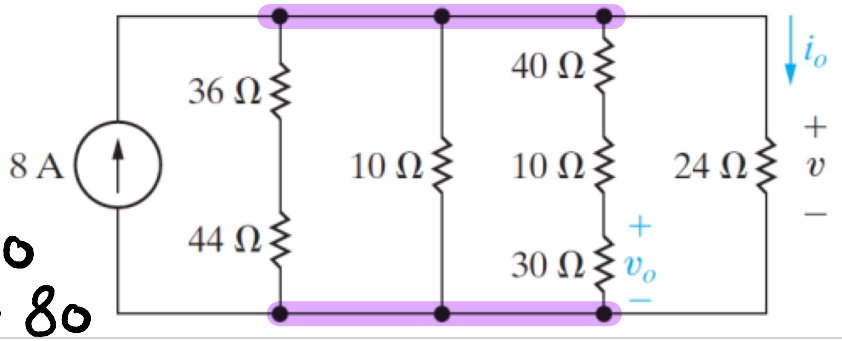
$$I_1 = \frac{R_2}{R_2 + R_1} * I_s \quad , \quad I_2 = \frac{R_1}{R_1 + R_2} * I_s$$



Examde 3

Use CDR to find i_o

Use VDR to find v_o



① 44 with 36 : 44 + 36 = 80

40 , 30, 10 : 40+30+10 = 80

Req of the highlighted :

$$\frac{1}{Req} = \frac{1}{80} + \frac{1}{80} + \frac{1}{10} \Rightarrow \frac{1}{Req} = \frac{10}{80} \Rightarrow Req = 8\Omega$$

$$i_o = \frac{8}{8+24} * 8 \Rightarrow i_o = 2A$$

② $$Req = \frac{24*8}{24+8} \Rightarrow Req = 6\Omega$$

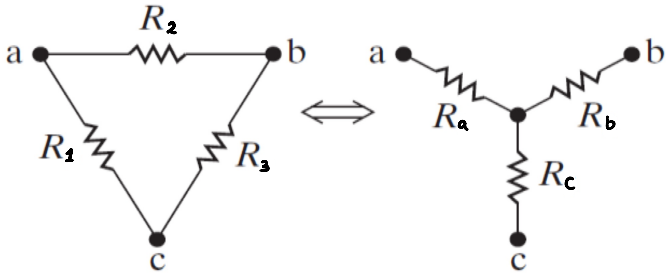
$$V = IR \Rightarrow V = 8*6 \Rightarrow V = 48 \text{ volt}$$

$$V_0 = \frac{30}{30+50} * 48 \Rightarrow V_0 = 18 \text{ volt}$$

Delta to wye transformation (Δ → Y)

important note to remember

- المقام دائماً ثابت
- قبل التحويل ⇐ R_1 قبل a ، R_2 قبل b ....
- بعد التحويل ⇐ R_a بعد a ، R_b بعد b ....



The Rule :-

$$R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3} \quad \| \quad R_b = \frac{R_2 R_3}{R_1 + R_2 + R_3} \quad \| \quad R_c = \frac{R_3 R_1}{R_1 + R_2 + R_3}$$

Notice that

$$R_x = \frac{\text{The resistors that are connected with } R_x}{R_1 + R_2 + R_3}$$

Wye to Delta transformation (Y → Δ)

The Rule :-

$$R_1 = \frac{R_a R_b + R_b R_c + R_a R_c}{R_b}$$

$$R_2 = \frac{R_a R_b + R_b R_c + R_a R_c}{R_c}$$

$$R_3 = \frac{R_a R_b + R_b R_c + R_a R_c}{R_a}$$

Notice that

- البسط دائماً ثابت
وهو حاصل ضرب كل المقاومات

- المقام يكون المقاومة التي لا تتصل مع المقاومة المراد حسابها